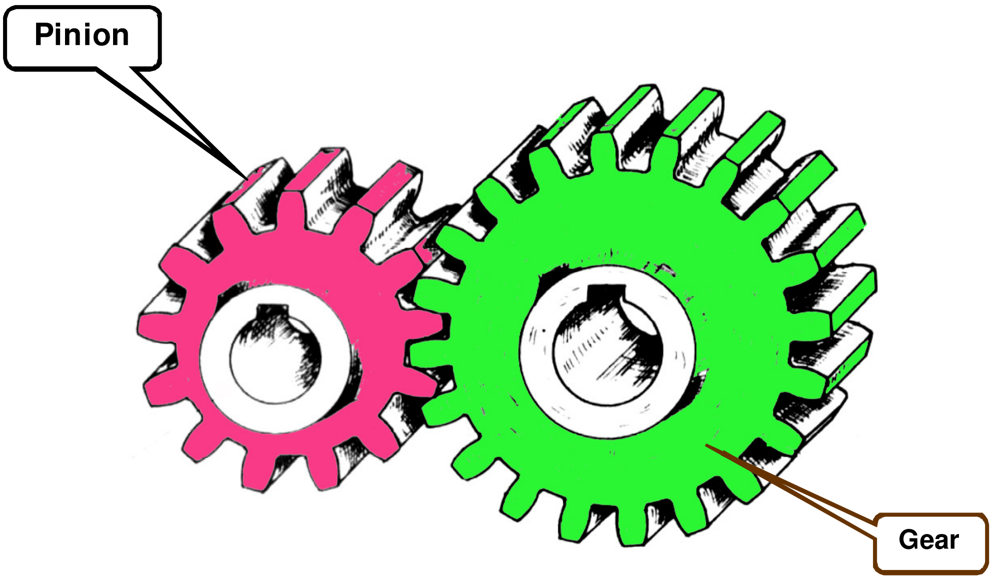
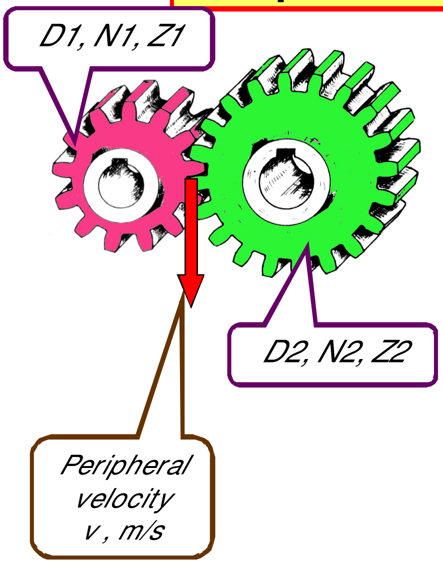
Spur Gears

Meshing Gear Pair



Peripheral Speed & Speed Ratio



$$v = \frac{\pi D_1 N_1}{60x1000} = \frac{\pi D_2 N_2}{60x1000}$$

mm, RPM, m/s

Speed Ratio

$$u = \frac{D_2}{D_1} = \frac{Z_2}{Z_1} = \frac{N_1}{N_2}$$

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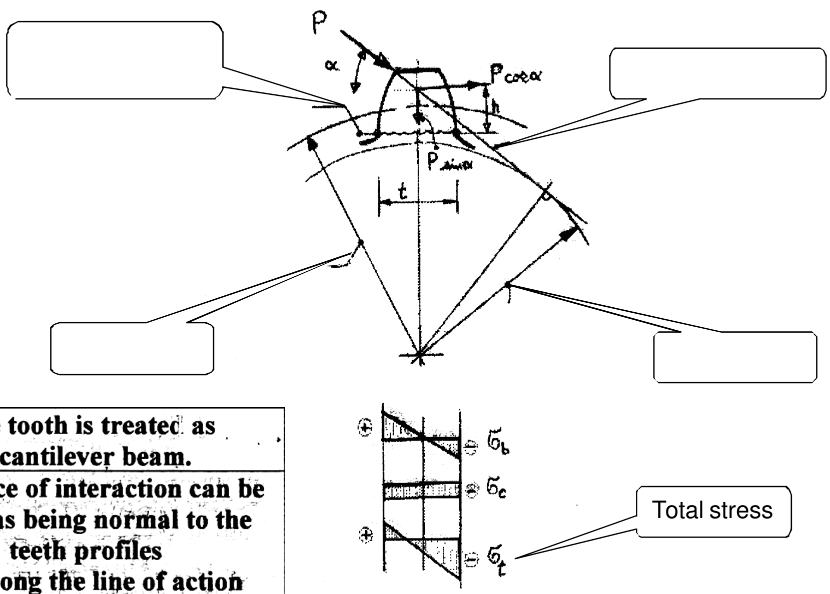
Strength Calculations for Spur Gears

Basic Assumptions



The tooth is treated as a cantilever beam.

The force of interaction can be taken as being normal to the teeth profiles (i.e. along the line of action which is tangent to the base circle).

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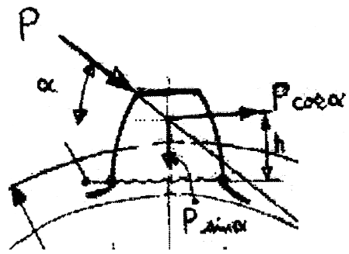
Strength Calculations for Spur Gears
Basic Assumptions

The force of interaction between a single pair of mating teeth remains constant in transmitting a constant torque.

The force is applied to the top of the tooth, where the arm of the force is maximal.

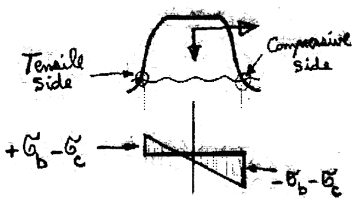
To simplify calculations, the force is moved along the line of action to the axis of the tooth and is resolved into two components:
1. P * cos α which bends the tooth
2. P * sin α which compresses the tooth



Strength Calculations for Spur Gears
Basic Assumptions

The dangerous cross section is at the root of the tooth in the zone of maximum stress concentration.

The critical section is the one where fatigue cracks and failure begins i.e. the *tensile* side.

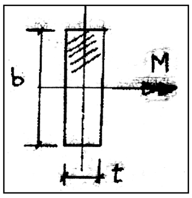


Strength Calculations for Spur Gears

Basic Assumptions

$$\sigma = \sigma_b - \sigma_c$$

$$= \frac{M\,y}{I} - \frac{P * \sin\alpha}{A}$$



$$\sigma = \frac{P\cos\alpha\ h * t}{2 * \frac{bt^3}{12}} - \frac{P\sin\alpha}{b\,t}$$

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Static Bending Strength of Teeth

Modified Lewis Formula

Assumptions of Lewis:
- -Pt acts at the PCD
- -Load
- -Load

$$P_t = \sigma_b \frac{k_y\ k_v}{k_s}\ b\ m$$

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Static Bending Strength of Teeth

Gear Face Width: b
b/m = 6-10 for cast teeth
10-25 for machined teeth

Velocity: m/s
1-10 slow
10-20 medium
>20 high

T {kgcm}=71620 x (HP/N)
T {Nm} =9550 x (KW/N)

Slow	Milling	Industrial or commercial
Medium	Grinding	Accurate
High	Lapping	precision

K_v = 3 / [3+v] v up to 10 m/s
= 6 / [6+v] v up to 20 m/s
= 5.5 / [5.5+sqrtv] v > 20 m/s

Module Series

Module Series for Gears mm DIN 780

From	Interval	To
0.3	0.1	1
1	0.25	4
4	0.5	7
7	1	16
16	2	24
24	3	45
45	5	75

Modified Form Factor Ky

1. Full depth tooth (2.2 m)

z	15°	20°	z	15°	20°	z	15°	20°
10	0.176	0.201	20	0.283	0.320	40	0.305	0.389
11	0.192	0.226	21	0.289	0.326	45	0.308	0.399
12	0.210	0.243	22	0.292	0.330	50	0.314	0.408
13	0.223	0.264	23	0.296	0.333	60	0.319	0.421
14	0.235	0.276	24	0.302	0.337	70	0.327	0.429
15	0.245	0.289	25	0.305	0.340	80	0.336	0.436
16	0.255	0.295	26	0.308	0.344	90	0.340	0.442
17	0.264	0.302	28	0.314	0.352	100	0.346	0.446
18	0.270	0.308	30	0.318	0.358	150	0.368	0.458
19	0.277	0.314	35	0.327	0.373	Rack	0.390	0.489

2. Stub tooth (1.8 m)

$$K_y = 0.54 - 3/z$$

Properties of Gear Materials

1. CAST IRON (Grey) DIN 1691

	C %	σ_{ut} kg/mm^2	E kg/mm^2	HB kg/mm^2
Normal				
GG-12	3.3 3.6	12	4000 7000	140 160
GG-14	3.3 3.6	11 18	5500 9500	140 160
GG-18	3.3 3.5	15 22	8000 10500	160 180
High Duty				
GG-22	3.2 3.4	19 26	9500 12000	180 200
GG-26	2.8 3.2	23 28	11000 13000	200 220
Special				
GG-30	2.6 3.0	25 30		200 240

GG : GrauguB

Properties of Gear Materials

2. CAST IRON (Malleable) DIN 1692

White Heart		
Normal GTW-35	34 36	125 160
High Duty GTW-40	38 41	125 220
Black Heart		
Normal GTS-35	35	120
High Duty GTS-38	38	120 140

GTW : WeiBer TemperguB
GTS : Schwarzer TemperguB

Properties of Gear Materials

3. CAST STEELS (Unalloyed) DIN 1681

	C%	σ_{u_t} kg/mm^2	σ_y kg/mm^2	HB kg/mm^2
GS-38 GS-C15	0.15	38	18	
GS-45 GS-C25	0.25	45	22	
GS-52 GS-C35	0.35	52	25	
GS-60 GS-C45	0.45	60	36	

GS : StahlguB
C : Carbon

Properties of Gear Materials

4. PLAIN CARBON STEELS DIN 1611 , 1612

St 34	0.12	34 42	19	95 120
St 37	>0.1	37 45	20	100 130
St 42	0.25	42 50	22	115 145
St 50	0.35	50 60	25	135 170
St 60	0.45	60 70	30	165 200
St 70	0.60	70 85	34	195 245

Properties of Gear Materials

5. CASE HARDENING STEELS (Unalloyed) DIN 17006, 17210

Quality Steels

C10	0.10 P : 0.045	42 52	25	130
C15	0.15 P : 0.045	50 65	30	140

High Quality Steels

CK10	0.10 P : 0.035	42 52	25	130
CK15	0.15 P : 0.035	50 65	30	140

Properties of Gear Materials

6. HEAT TREATABLE STEELS (Unalloyed) DIN 17006, 17200

Quality Steels

C22	0.22 P : 0.045	50 60	30	155
C35	0.35 P : 0.045	60 72	37	172
C45	0.45 P : 0.045	65 80	40	206
C60	0.60 P : 0.045	75 90	49	243

High Quality Steels

CK22	0.22 P : 0.035	50 60	30	155
CK35	0.35 P : 0.035	60 72	37	172
CK45	0.45 P : 0.035	65 80	40	206
CK60	0.60 P : 0.035	75 90	49	243

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Properties of Gear Materials

7. CASE HARDENING STEELS (Alloyed) DIN 17210

St 34, C15			
annealed	34	18(end.)	100
hardened	60	26 ben.	600
20 Mn Cr 5			
annealed	60	28	170
hardened	120	60	600
18 Cr Ni 8, 42 Cr Mo 4			
annealed	65	32	190
hardened	140	60	600

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Properties of Gear Materials

8. HEAT TREATABLE STEELS (Alloyed) DIN 17200

	σ_{u_t} kg/mm^2	σ_{en} kg/mm^2	HB kg/mm^2
St 60, C45			
annealed	60	26	170
heat treated	70	30	[illegible]
	100	42	280
St 70, C60			
annealed	70	30	200
heat treated	80	34	[illegible]
	100	42	280
37 Mn Si 5			
annealed	60	29	170
heat treated	80	36	230
	105	50	300
50 Cr V 4			
annealed	70	34	200
heat treated	115	56	330
	140	68	400

Dynamic Loading

The Dynamic Load or Impact Load is not an external load applied to the system, thus it could be termed:

Due to errors resulting from:

-manufacturing and assembly: such errors cause short periods of which are increased by the of the teeth.

-elastic deflection of the teeth

We obtain:

-non-uniform rotation of the gear when the pinion rotates at uniform speed.

Thus:

-the instantaneous

-the average

This leads to:

-impact (dynamic) loading on the teeth

Thus the gears operate under:

To minimize probability of **Failure** in teeth, is proposed to:

-reduce friction losses

-dissipate the heat generated in the gears

-prevent

Dynamic Loading

$$P_d = P_t + \frac{K_d \cdot b + P_t}{1 + \frac{0.15}{V}\sqrt{K_d \cdot b + P_t}}$$

$$P_d = P_t + \Delta P_t$$

K_d → inaccuracy in m/cing
→ tooth vibration

k:
- 0.107 — $14\frac{1}{2}^\circ$ tooth
- 0.111 — 20° full depth
- 0.115 — 20° stub tooth

Errors in Gears

Error in Tooth Profile
- → Probable Error
- → Permissible Error

Errors in Gears

Permissible Error in Gears (Velocity, m/s / Error, mm)

1 / 0.1250	2 / 0.1000	3 / 0.0950
4 / 0.0863	5 / 0.0625	6 / 0.0550
7 / 0.0500	8 / 0.0438	9 / 0.0388
10 / 0.0375	12 / 0.0263	15 / 0.0250
20 / 0.0143	25 / 0.0135	30 / 0.0125
35 / 0.0095	50 / 0.0095	

Errors in Gears

Probable Error in Gears mm

Module mm	Class of Workmanship: Commercial	Accurate	Precision
up to 4.5	0.0500	0.0250	0.0125
6	0.0600	0.0300	0.0150
7	0.0700	0.0350	0.0175
8	0.0800	0.0400	0.0200
12	0.1000	0.0500	0.0250
25	0.1200	0.0600	0.0300

Endurance Strength

The Endurance Strength determines the degree of safety. The endurance strength is estimated by applying the
We use to count for the stress concentration at the base of the tooth.

$$P_{en} > P_d$$

$$\text{Margin of Safety} = \frac{P_{en} - P_d}{P_d}$$

- 25% Steady Transmitted Load
- 35% Pulsating Ld
- 50% Shock Ld

Wear Resistance

Gears in continuous service lose their usefulness because of excessive wear

Forms of Wear:

1. *Pitting: due to the presence of dynamic loading and causes*
2. *Abrasion: due to the presence of .*
3. *Scoring: due to*
4. *Scuffing: due to the*
5. *Seizing: due to accompanied by a locally generated heat which*

Wear Resistance

The limiting load for wear Pw is the load

$$P_w = K_w \cdot b \cdot d_p \cdot K_n$$

Ld. stress Factor

Load Stress Factor kg/sq.mm

Material of Pinion/Gear	BHN of Pinion/Gear	15°	20°
Steel/Steel	150 / 150	0.022	0.029
	200 / 150	0.031	0.042
	250 / 150	0.042	0.056
	200 / 200	0.045	0.060
	250 / 200	0.055	0.072
	300 / 200	0.070	0.092
	250 / 250	0.075	0.095
	300 / 250	0.086	0.114
	350 / 250	0.100	0.138
	300 / 300	0.105	0.140
	350 / 300	0.120	0.164
	400 / 300	0.130	0.180
	350 / 350	0.150	0.200
	400 / 350	0.170	0.220
	450 / 350	0.190	0.240